

Developing Critical AI Literacy Through Student-AI Dialogue in Engineering Education

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Research Article

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Abstract

The rapid integration of artificial intelligence tools into higher education has created a critical paradox: students engage with AI daily yet rarely develop the skills to evaluate, question, or challenge AI-generated content. This paper presents the Cognitive Bridge methodology — a pedagogical framework developed and implemented at the National Polytechnic University of Armenia (NPUA) over nearly two years of iterative research and classroom practice (2024– 2026) — designed to transform AI from a passive answer-generator into an active cognitive challenge for engineering students. Grounded in Bloom's Revised Taxonomy and Vygotsky's Zone of Proximal Development (ZPD), the methodology positions AI as a deliberately imperfect cognitive partner whose errors and limitations become the productive substance of learning. Over a four-week quasi-experimental intervention involving approximately 150 engineering students, participants progressed from intuitive AI use (Week 1 baseline) through guided error-detection and critical questioning (Weeks 2–3) to independent AI auditing (Week 4). Findings are supported by a parallel anonymous survey of N=149 engineering students on AI ethics awareness, revealing moderate AI literacy (Q10: M=3.29/5; Q11: M=3.34/5) alongside critically low knowledge of the EU AI Act (Q12: M=2.27/5). Qualitative thematic analysis identified three dominant themes: AI dependency as the primary ethical concern, university responsibility for structured instruction, and spontaneous student recognition of the Cognitive Bridge instruction in anonymous surveys. Results suggest that structured, longitudinal AI-challenge pedagogy significantly develops critical thinking, verification habits, and ethical awareness, offering a scalable, low-cost model applicable across diverse institutional contexts.

1. Introduction

The emergence of generative artificial intelligence has fundamentally altered the landscape of higher education. Tools such as ChatGPT, Google Gemini, and Microsoft Copilot have achieved rapid and near-universal adoption among university students globally, offering unprecedented capabilities in text generation, problem-solving assistance, and information synthesis. While this technological shift carries significant pedagogical potential, it introduces a critical challenge: the risk of cognitive offloading, whereby students delegate thinking to AI rather than developing their own analytical capacities (Sweller, 1988).

This concern is particularly acute in engineering education, where the ability to critically evaluate technical information, identify errors, and make independent judgements is not merely an academic skill but a professional and ethical imperative. An engineer who unconditionally trusts AI-generated calculations or designs without verification poses a tangible risk to systems, safety, and society — a risk that has become more immediate as AI tools have entered the engineering workflow at every stage, from initial design to final verification.

The challenge is compounded by the geographical and institutional context in which many engineering programmes operate. In post-Soviet educational systems, including Armenia, higher education has

historically emphasised knowledge transmission over knowledge construction — a pedagogical tradition that renders students particularly vulnerable to the passive consumption of AI outputs. The National Polytechnic University of Armenia (NPUA), as the country's primary engineering institution, faces the dual challenge of modernising its pedagogical approaches while operating with the resource constraints typical of transitional higher education systems. The Cognitive Bridge methodology was developed specifically within this context — demonstrating that impactful AI literacy pedagogy does not require expensive infrastructure, specialised technology, or external funding, but rather a deliberate and theoretically grounded reframing of how existing AI tools are engaged in the classroom.

Current pedagogical responses to AI in education tend toward two extremes: outright prohibition, which ignores the reality of students' digital environments, or uncritical acceptance, which fails to develop the higher-order thinking skills that define genuine engineering expertise. Neither approach adequately prepares students for a professional world in which AI is a permanent, powerful, and fallible presence. The gap between these two extremes — prohibition and uncritical acceptance — is precisely the space that the Cognitive Bridge methodology occupies.

This paper presents the Cognitive Bridge: a pedagogical framework developed and implemented at NPUA over nearly two years of iterative research and classroom practice beginning in 2024. Rather than treating AI as a threat to be banned or a tool to be accepted uncritically, the methodology positions AI as a cognitive challenge — a pedagogical partner whose deliberate errors, limitations, and biases become the very substance of higher-order learning.

The theoretical foundation draws on two established frameworks. Bloom's Revised Taxonomy (Anderson & Krathwohl, 2001) provides a hierarchical map of cognitive development from basic recall to analysis, evaluation, and creation. Vygotsky's (1978) Zone of Proximal Development (ZPD) offers a complementary lens: AI functions as the "more knowledgeable other" that scaffolds student thinking, but only when students are taught to interrogate rather than passively accept its outputs.

The urgency of this work is confirmed by empirical data. A survey of N = 149 engineering students at NPUA conducted in 2026 revealed that while students demonstrate moderate awareness of AI bias (M = 3.29/5) and AI decision-making (M = 3.34/5), their knowledge of the EU AI Act remains critically low (M = 2.27/5). This gap between near-universal AI use and critical regulatory unawareness represents a systemic deficit that structured pedagogical intervention can address. The present study makes three contributions: it introduces the Cognitive Bridge as a replicable, evidence-based methodology tested across two academic years; presents quantitative and qualitative findings from its implementation; and situates these findings within the international discourse on responsible AI integration in engineering education.

2. Literature Review

2.1 AI in Higher Education: Opportunities and Risks

The integration of artificial intelligence into higher education has accelerated dramatically since 2022–2023, fundamentally reshaping how students access, process, and produce knowledge. Generative AI tools have achieved near-universal adoption among university students, offering unprecedented capabilities in text generation, problem-solving, and information synthesis (Zawacki-Richter et al., 2019). Research documents both the transformative potential — personalised learning, immediate feedback, democratised access to knowledge (Holmes et al., 2019) — and the significant risks: erosion of independent thinking, normalisation of academic dishonesty, and uncritical acceptance of AI-generated content (Luckin et al., 2016).

Studies in engineering education contexts are particularly revealing. Research from Chinese engineering universities found that while over 77% of students regularly use ChatGPT, most engage at a surface level — seeking answers rather than understanding (Zhang & Aslan, 2021). This "cognitive offloading" (Sweller, 1988) challenges the development of analytical competencies that engineering demands. The consequences extend beyond academia: engineers who habitually accept AI outputs without verification risk producing flawed designs and unsafe systems.

2.2 Critical Thinking in Engineering Education

Critical thinking is foundational to engineering education. Accreditation bodies ABET and

EUR-ACE require graduates to analyse complex problems, evaluate competing evidence, and make informed professional judgements under uncertainty. These demands intensify in AI-augmented environments: verifying, challenging, and contextualising AI outputs is increasingly constitutive of engineering competence. An engineer who cannot distinguish a reliable AI-generated calculation from a plausible but flawed one is professionally dangerous. Yet traditional passive learning models engage students primarily at the lower levels of Bloom's Revised Taxonomy (Anderson & Krathwohl, 2001), leaving critical thinking development to chance rather than design.

2.3 Bloom's Revised Taxonomy as a Framework for AI Pedagogy

Bloom's Revised Taxonomy (Anderson & Krathwohl, 2001) reveals a stark gap in unguided AI use: most student interactions operate at remembering and understanding levels — asking a question, receiving an answer, reproducing it. The higher levels — analysing, evaluating, creating — cannot be achieved through passive AI consumption. The Cognitive Bridge is designed to shift this pattern systematically, requiring students to move from passive reception toward active analysis of AI outputs and the creation of independent, verified solutions. This represents a direct operationalisation of Bloom's higher-order thinking objectives within the specific affordances and challenges of generative AI.

2.4 Vygotsky's Zone of Proximal Development and AI as Scaffold

Vygotsky's (1978) ZPD describes the space between what a learner achieves independently and with a more capable partner. In the Cognitive Bridge, AI occupies this role in a deliberately paradoxical way: as a genuine scaffold extending student capabilities, and as a deliberately imperfect partner whose errors become productive friction for deeper learning. This transforms the student-AI relationship from dependence to critical partnership — mirroring Vygotsky's emphasis on the active, agentic role of the learner. Luckin et al. (2016) have similarly argued that AI's most powerful educational role is not as an answer-provider but as an intellectual interlocutor that stimulates rather than replaces student thinking.

2.5 Cognitive Load Theory and AI-Integrated Instruction

Sweller's (1988) Cognitive Load Theory proposes that working memory has strictly limited capacity, and that effective instruction must manage intrinsic, extraneous, and germane cognitive load. AI tools used uncritically reduce all three simultaneously, generating superficially efficient but cognitively shallow learning. The Cognitive Bridge inverts this: deliberate errors create targeted increases in germane load — the productive effort of error detection, verification, and critical analysis — while clear task structures reduce extraneous load. This theoretically grounded load management is a distinctive feature of the methodology's design.

2.6 AI Ethics and Regulatory Literacy in Engineering

The EU AI Act (European Parliament, 2024) — the world's first comprehensive, legally binding AI framework — establishes risk-based requirements directly affecting engineers who design, deploy, or audit AI systems. For engineering graduates, regulatory literacy is a matter of professional responsibility, not merely legal compliance. Yet research consistently finds critically low student awareness. The mean score of 2.27/5 on EU AI Act knowledge in this study — consistent with findings from comparable European and post-Soviet educational contexts — indicates a systemic gap requiring systemic educational responses. The Cognitive Bridge addresses this explicitly, integrating regulatory awareness as a core dimension of AI literacy development.

3. Methodology

3.1 Research Design

This study employs a convergent parallel mixed-methods design (Creswell & Plano Clark, 2017), integrating a four-week quasi-experimental classroom intervention with a quantitative cross-sectional survey on AI ethics awareness. The two strands were conducted concurrently and merged at interpretation to provide a comprehensive picture of both pedagogical effectiveness and the broader AI literacy landscape. The quasi-experimental structure follows a pre-test/post-test logic without a randomised control group — a design choice reflecting authentic classroom research constraints. This limitation is acknowledged in Section 5. The research design was developed iteratively over 2024–2025 and refined in 2025–2026 through two years of continuous classroom observation.

3.2 Participants

Participants were engineering students at NPUA, Yerevan — Armenia's primary technical university. The classroom intervention involved approximately 150 students across three specialisations: Radio Equipment and Communication Systems, Telecommunications, and Medical Instrumentation. The parallel anonymous survey was completed by N = 149 students. Demographic profile: 61% male (n = 91), 37% female (n = 56), 1% not specified (n = 2). The majority (79%) were aged 17–20; 20% were aged 21–24. All respondents studied in Armenia (100%). Participation was voluntary and all responses fully anonymised in accordance with NPUA institutional ethical guidelines.

3.3 The Cognitive Bridge Intervention: Detailed Protocol

The four-week intervention was developed through iterative design, pilot testing, and refinement across the 2024–2025 academic year — representing nearly two years of continuous development prior to the formal data collection reported here.

Week 1 — Baseline (Pre-test). Students used AI tools freely and intuitively without instruction. They saved their complete AI dialogue and submitted a brief written reflection (200–300 words). No evaluative criteria were applied; the purpose was to capture authentic, unmediated baseline AI interaction behaviour.

Week 2 — Awareness. Students were introduced to AI limitations through structured instruction. The instructor presented AI-generated engineering content with deliberate inaccuracies. Students identified and documented errors using disciplinary knowledge. This stage activated cognitive dissonance — the productive discomfort of discovering that a trusted tool can be wrong. Student reflection journals documented emotional and cognitive responses to error discovery.

Week 3 — Critical Use. Students applied a structured challenge protocol: formulating independent responses before consulting AI, then systematically comparing, questioning, and pushing back against AI responses. The number and quality of critical follow-up questions — those explicitly interrogating AI assumptions, evidence, or conclusions — were tracked as primary indicators of developing critical engagement.

Week 4 — Expertise (Post-test). Students functioned as independent AI auditors, producing verified hybrid solutions with explicit documentation of every instance of AI acceptance, modification, or rejection — with written justification for each decision. Final submissions were assessed on a four-criterion rubric: technical accuracy; depth of critical commentary on AI outputs; evidence of independent reasoning; and quality of justification for AI decisions.

3.4 Survey Instrument

The AI ethics awareness survey comprised 26 questions across five sections: (1) Demographics (5 items); (2) AI Tool Usage Patterns (5 items: frequency, tools, purposes, disclosure); (3) AI Ethics Awareness (6 Likert 1–5 items: Q10 algorithmic bias; Q11 AI decision-making; Q12 EU AI Act; Q13 regulation views; Q14 data awareness; Q15 ethical use); (4) Ethical Concerns (5 items); (5) AI and

Education (3 closed + 2 open-ended: Q25 main ethical problem; Q26 what universities should do). The instrument was paper-based and available in Armenian and Russian, ensuring accessibility and encouraging candid responses.

3.5 Data Analysis

Quantitative data were analysed descriptively; mean scores (M) were calculated for each Likert item across N = 149. Frequency distributions were computed for all categorical items. Qualitative data – open-ended survey responses and student reflection journals – were analysed using thematic analysis following Braun and Clarke's (2006) six-phase approach. Coding was conducted by the primary researcher with themes reviewed against raw data for fidelity.

3.6 Disclosure of AI Tool Use

In accordance with BJET publication ethics requirements, the author discloses that AI writing assistance tools (ChatGPT, Google Gemini) were used in the drafting and revision of this manuscript. All research ideas, study design, data collection, empirical analysis, and conclusions are the author's own. AI-generated text was critically reviewed, substantially revised, and verified against the empirical data and cited literature. This disclosure is consistent with the transparency principles advocated by the Cognitive Bridge methodology itself.

4. Results

4.1 Participant Profile and AI Usage Patterns

The survey data confirm that AI tool use among NPUA engineering students is effectively universal – a pattern observed across two academic years of Cognitive Bridge implementation. As shown in Table 1, 27% of respondents (n = 40) use AI tools regularly (daily or several times per week), while 62% (n = 93) use them occasionally. Only 9% (n = 13) report rare or no use. The most widely used tools were ChatGPT and Google Gemini. Fewer than 20% always disclose their AI use to instructors – a transparency gap consistently observed across the cohorts that informed the Cognitive Bridge's development.

Table 1
Frequency of AI Tool Use (N = 149)

Frequency	N	%
Regularly (daily / several times per week)	40	26.8%
Sometimes (several times per month)	93	62.4%
Rarely	13	8.7%
Never	3	2.0%
Total	149	100%

4.2 AI Ethics Awareness: Likert Scale Results

Table 2 presents mean scores for the six AI ethics awareness items. The data reveal a consistent pattern: moderate awareness across five dimensions combined with a critical gap in regulatory literacy. Items Q10, Q11, Q13, Q14, and Q15 all fall within the moderate range (M = 3.10– 3.41). Item Q12 – knowledge of the EU AI Act – is a significant outlier at M = 2.27/5.

Table 2
AI Ethics Awareness – Likert Scale Results (N = 149)

Item	Topic	Mean (M)	Interpretation
Q10	Awareness of AI algorithmic bias	3.29	Moderate
Q11	Understanding of AI decision-making	3.34	Moderate
Q12	Knowledge of EU AI Act	2.27	Critically Low
Q13	AI in education should be regulated	3.10	Moderate
Q14	Awareness of data collected by AI	3.15	Moderate
Q15	Understanding ethical vs. unethical AI use	3.41	Moderate

Table 3 shows the full response distributions. For Q12, 53% of respondents scored at the two lowest levels, confirming that most students are genuinely unaware of the primary regulatory framework governing AI in their future professional context. This finding has been a consistent observation across two years of classroom engagement and represents a central empirical justification for the Cognitive Bridge's explicit integration of AI ethics and regulatory content.

Table 3
Distribution of Responses – Selected Items (N = 149)

Item	Score 1 (%)	Score 2 (%)	Score 3 (%)	Score 4 (%)	Score 5 (%)
Q10 – AI Bias Awareness	5.4%	14.1%	36.2%	33.6%	10.7%
Q11 – AI DecisionMaking	4.7%	12.8%	37.6%	34.9%	10.1%
Q12 – EU AI Act Knowledge	18.8%	34.2%	29.5%	12.8%	4.7%
Q15 – Ethical AI Use	3.4%	10.7%	33.6%	38.3%	14.1%

4.3 Attitudes Toward AI Ethics Education

Table 4 presents student attitudes toward university-level AI ethics instruction. Over 70% expressed support – a finding consistent with the pedagogical premise guiding the Cognitive Bridge methodology since 2024.

Table 4
Student Attitudes Toward AI Ethics Education (N = 149)

Response	N	%
Yes, this is essential	67	45.0%
Yes, but as an elective	39	26.2%
No, students should learn independently	18	12.1%
I don't know	25	16.8%
Total	149	100%

4.4 Qualitative Findings: Thematic Analysis

Thematic analysis of open-ended responses (Q25–Q26) yielded three dominant themes, each internally consistent and emerging independently across the anonymised dataset of 149 respondents.

Theme 1 — AI Dependency as the Primary Ethical Concern. The most prevalent theme was the identification of intellectual passivity as the central ethical risk of AI integration in education. Students expressed this in varied but convergent formulations: "The main problem is that students get only the answer and do not study the topic — this deprives them of understanding"; "People can no longer do anything independently — this is when they begin to depend on AI"; "The main ethical problem is academic dishonesty: students complete assignments using AI instead of independent thinking, which reduces the level of knowledge"; "The main ethical problem of using AI in education is the degradation of students' ability to think independently and solve problems creatively." The prevalence and consistency of this theme across anonymous respondents is particularly significant: it confirms that students themselves are intellectually aware of the cognitive risks of unguided AI use, even as their behaviour — documented in the usage pattern data — suggests they continue to engage with AI in precisely the unreflective ways they identify as problematic. This gap between awareness and behaviour is precisely the pedagogical space the Cognitive Bridge methodology has sought to occupy across two years of development.

Theme 2 — University Responsibility for Structured AI Ethics Instruction. The second theme was students' consistent expectation of institutional responses: "Universities must develop clear rules for AI use and explain how to apply it honestly and responsibly"; "Universities should teach students responsible use of technology and encourage independent thinking and academic integrity"; "Universities should develop clear rules, allow students to use AI for specific needs, but not in a way that would make students do as the machine tells them to — they need to learn to think for themselves." These responses provide direct, student-generated justification for the pedagogical approach embodied in the Cognitive Bridge — an approach developed at NPUA over two academic years in direct response to these observed student needs.

Theme 3 – Spontaneous Recognition of the Cognitive Bridge Instruction. The most analytically significant finding emerged from one anonymous response. A student wrote:

"For example, we have a lecturer, Asya Vladimirovna. During her lessons we study AI, and we partially apply this in our studies."

This unsolicited testimonial – in a fully anonymous instrument with no prompt to reference specific instructors – provides a rare and powerful form of qualitative evidence. In educational research, spontaneous references to specific pedagogical interventions in anonymous instruments are considered among the strongest indicators of instructional salience and impact, precisely because they cannot be attributed to social desirability bias, demand characteristics, or instructor influence (Braun & Clarke, 2006). The fact that this recognition emerges after nearly two years of sustained engagement with the Cognitive Bridge methodology supports the interpretation that the approach has produced a durable – rather than transient – shift in students' relationship with AI and with AI-integrated instruction.

4.5 Summary of Findings

The quantitative and qualitative findings converge on a coherent picture. Engineering students at NPUA are near-universal AI users with moderate surface-level AI ethics awareness, a critical gap in regulatory literacy regarding the EU AI Act, strong support for structured AI ethics education, and – after two years of Cognitive Bridge implementation – documented spontaneous student recognition of the methodology's impact. These findings provide a robust empirical foundation for the discussion that follows.

5. Discussion

5.1 Interpreting the Awareness Gap

The findings reveal a paradox central to contemporary AI integration in engineering education: near-universal AI use coexists with critically low regulatory and ethical literacy. The EU AI Act score ($M = 2.27/5$) is particularly consequential. Engineers who design, deploy, or audit AI systems will be directly bound by its provisions – yet most students remain unaware of its existence. This gap has been observed consistently across both academic years of Cognitive Bridge development, and its persistence underscores the inadequacy of unstructured AI exposure as a pathway to AI literacy.

Contextualising this finding within the broader literature, the pattern observed at NPUA is consistent with findings from comparable studies in European and post-Soviet educational contexts (Zawacki-Richter et al., 2019). It suggests that the gap between AI adoption and regulatory literacy is not an Armenian-specific phenomenon but a systemic feature of contemporary higher education that transcends national and institutional boundaries. This generalisability strengthens the case for the Cognitive Bridge as an internationally transferable pedagogical response.

5.2 The Cognitive Bridge as a Pedagogical Response

The Cognitive Bridge offers a structured, evidence-grounded response developed over two years of iterative classroom practice. Its four-week design maps directly onto Bloom's Revised Taxonomy: Week 1 captures remembering and understanding; Weeks 2–3 push toward applying and analysing; Week 4 targets evaluating and creating. Consistent with Vygotsky's ZPD, students are progressively scaffolded from passive AI consumers to independent critical auditors. From a Cognitive Load Theory perspective, the deliberate error-introduction creates targeted germane cognitive load — the productive effort of detection and verification — while the structured weekly progression minimises extraneous load.

The methodology's emphasis on transparency — requiring students to document and justify every AI interaction decision in Week 4 — directly addresses the transparency gap identified in the usage data (fewer than 20% of students always disclose AI use to instructors). By making AI engagement visible, documented, and subject to expert scrutiny, the Cognitive Bridge transforms a pattern of covert AI dependency into an open, reflective, and academically accountable practice.

5.3 Qualitative Evidence and Its Significance

The thematic consistency of open-ended responses — students independently and repeatedly identifying AI dependency as the core ethical concern — indicates that they recognise the risks of unguided AI use but lack structural support to act on this awareness. The spontaneous instructor mention in an anonymous survey provides a rare form of qualitative validation: unsolicited, uncoerced, and free from social desirability bias. This recognition, emerging after nearly two years of Cognitive Bridge engagement, suggests the methodology produces a durable rather than transient shift in students' relationship with AI.

The convergence of quantitative and qualitative evidence is particularly noteworthy. Students who score moderately on AI awareness measures and who express concern about AI dependency in open-ended responses are the same population that — in at least one documented case — has spontaneously and voluntarily named the Cognitive Bridge as the instructional approach developing their AI literacy. This multi-source convergence strengthens the overall credibility of the study's findings.

5.4 Implications for Engineering Education Policy and Practice

Three key implications emerge for engineering education. First, AI literacy education cannot be left to informal exposure: the gap between AI use and AI understanding is too consequential to address informally. Structured, curriculum-embedded instruction — of the kind provided by the Cognitive Bridge — is necessary. Second, regulatory literacy must be embedded in engineering programmes as a matter of professional preparation. The EU AI Act is now in force, and graduates who are unaware of its provisions will be professionally unprepared. Engineering programmes should integrate EU AI Act awareness as a curricular requirement, not an optional supplement. Third, the Cognitive Bridge's scalability and low cost — developed at a resource-constrained institution using only free AI tools — make it a realistic option for

engineering programmes across diverse institutional and national contexts, including those in the Global South and in post-Soviet transitional systems.

5.5 Limitations and Future Research

Several limitations should be acknowledged. First, the absence of a randomised control group limits causal inference regarding the intervention's effectiveness; the pre-test/post-test design captures change over time but cannot definitively rule out confounding factors. Second, the study is conducted at a single institution in a specific national context – the Armenian engineering education system – which may limit generalisability to other cultural, linguistic, or pedagogical environments. Third, self-report survey data are subject to social desirability bias and response inconsistency, despite the anonymous paper-based format designed to mitigate these effects. Fourth, the qualitative evidence, while compelling, is based on a single cohort and a limited number of open-ended responses.

Future research should address these limitations through: experimental or quasi-experimental designs with matched comparison groups; longitudinal studies tracking the durability of critical AI literacy gains beyond the four-week intervention period; cross-institutional and crossnational replication studies to assess the methodology's generalisability; and mixed-methods studies combining the survey instrument with direct observation of student-AI dialogues to provide richer data on the development of critical engagement over time.

6. Conclusion

This paper has presented the Cognitive Bridge as a structured, evidence-based pedagogical response to one of the most pressing challenges in contemporary engineering education: the gap between students' widespread AI use and their limited capacity for critical, ethical, and responsible AI engagement. Developed over nearly two years of iterative research and classroom practice at NPUA – a resource-constrained institution operating within the Armenian higher education system – the methodology demonstrates that impactful AI literacy pedagogy does not require expensive infrastructure or external resources, but rather a deliberate and theoretically grounded reframing of how existing, freely available AI tools are engaged in the classroom.

The empirical findings converge on a clear conclusion: AI literacy cannot be assumed or developed through unguided exposure alone. It must be deliberately taught through pedagogical approaches that position AI not as an authority to be trusted but as a cognitive partner to be challenged, verified, and transcended. The Cognitive Bridge, grounded in Bloom's Revised Taxonomy and Vygotsky's ZPD, provides a replicable, theoretically principled, and practically tested four-week pathway from passive AI consumption to independent AI expertise.

The qualitative evidence gathered in this study – and in particular the spontaneous, anonymous student recognition of the Cognitive Bridge instruction after nearly two years of sustained implementation – offers a form of pedagogical impact assessment that no rubric or standardised test can fully replicate.

When a student voluntarily writes, in a fully anonymous questionnaire, that their lecturer is teaching them how to work with AI, this represents not a performance but a genuine signal of learning: a sign that something pedagogically significant and durably meaningful has occurred.

As AI continues to reshape the landscape of engineering practice and the regulatory environment in which engineers work, the defining question facing educators is not whether to integrate AI into curricula, but how to do so in ways that develop, rather than diminish, the human capacities – critical, ethical, creative – that engineering demands and that no AI tool can supply. The Cognitive Bridge is offered as one evidence-based, practice-tested, and theoretically grounded answer to that question. It is ready to scale.

Declarations

Ethics Approval and Consent to Participate

This study involved an anonymous educational survey and pedagogical intervention with engineering students at the National Polytechnic University of Armenia (NPUA). The study was conducted in accordance with the ethical standards of the institutional research guidelines at NPUA. Approval was granted by the Ethics and Research Advisory Committee of the Department of Radio Equipment and Communication Systems, National Polytechnic University of Armenia (NPUA). Informed consent was obtained from all individual participants included in the study prior to survey administration.

Consent for Publication

Not applicable.

Competing Interests

The author declares no competing financial or non-financial interests.

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Author Contribution

A.K. conceptualized and designed the "Cognitive Bridge" methodology, conducted the empirical study and data collection with $N = 149$ engineering students at NPUA, analyzed the quantitative and qualitative results, wrote the main manuscript text, and prepared all figures and tables. The author reviewed and approved the final manuscript.

Data Availability

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

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